

An electrostatic generator for 1 MV

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With 4 figures in the text

A non-pressurized van de Graaff generator for 1 MV maximum voltage, equipped with an acceleration tube, has been built at the Department of Physics, Royal Institute of Technology, Stockholm. It is designed for nuclear investigations, the first of which has recently been completed. (1)

The arrangement of the high-voltage hall is shown in Fig. 1. The pit in which the machine stands is sunk through the floor into the underlying rock to a depth of 4 meters. The irradiation room, where experiments are carried out, is at the bottom of this pit.

The electrostatic generator

The high voltage electrode (Figs. 1 and 2) is made from aluminium sheet, and has the shape of a cylinder with half-spherical ends. The radius is 75 cm. The electrode is supported by an interior wooden platform, which, including the equipment it carries, weighs about 400 kg. This assembly is mounted on a plexiglas column of 72 cm diameter, which is made up from four cylinders of wall thickness $3/8''$. These were made following a method developed by OHLIN and BECKMAN (2), who kindly put their wooden jig at our disposal. The iron rings between the cylinders are surrounded by corona shieldings in order to reduce the risk of break-down. The column is 315 cm long.

The two charging belts inside the column are made of fabric-armoured rubber. They are 48 cm wide. Fig. 1 shows the arrangement of the lower pulleys and the driving motor (12.5 h. p. D. C. motor). The belt speed is 30 m/s.

The belts are charged by means of spray bars, which are mounted at a distance of 5 mm from the belts. The lower pulleys act as second electrodes. More spray bars inside the high voltage electrode draw off the charge. The charge and hence the high voltage can be given positive or negative polarity. The charging unit can give 30 kV, 10 mA, but it has never been used at more than 10 kV, 1 mA.

The acceleration tube

The acceleration tube, which is 295 cm long, consists of 22 porcelain insulators of the type shown in Fig. 3. This figure also shows how the lower 20 of them are mounted. Between each pair of insulators is a lens-ring of chromium-plated

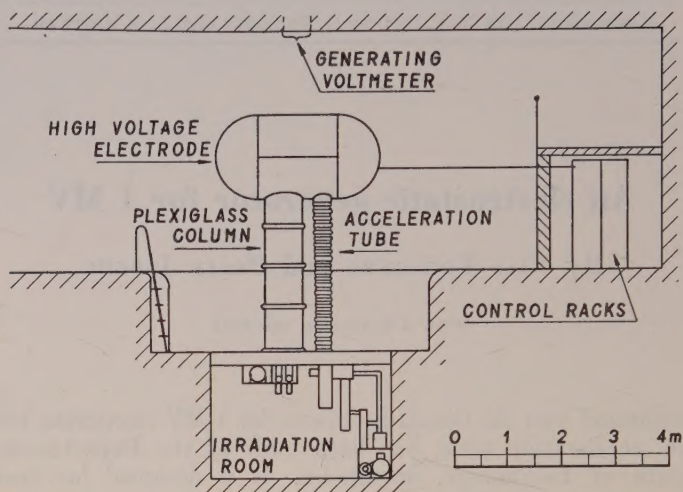


Figure 1. General arrangement of the high-voltage hall.

brass with slots for rubber gaskets. The chromium-plated acceleration lenses inside the tube are supported by the lens-rings. The insulators are clamped together with clips surrounded by aluminium corona shieldings.

Fig. 4 shows the electrostatic focusing system in the top of the acceleration tube and an ion source of a modified Werner type. (3) An electron gun can be substituted for the ion source. The two upper insulators and lens-rings are sealed together with polyvinylacetate.

When working with electrons it is also possible to focus the beam with a magnetic lens at the bottom of the tube. When working with ions this lens is used for deflecting the secondary electrons coming from the target. These electrons would otherwise be accelerated up the tube, loading the generator unnecessarily, and giving rise to penetrating X-rays.

The acceleration tube is evacuated by means of one mechanical pump and two oil diffusion pumps, working in series. The pumping speed of the high vacuum pump is nominally 500 l/s at 10^{-4} mm Hg. It is, however, reduced to about 100 l/s by a baffle and a liquid air trap, the purpose of which is to prevent oil vapour from condensing in the system. This is particularly important when a cooled heavy ice target is being used.

The ultimate vacuum is 10^{-5} mm Hg, when there is no inlet of gas, and $3 \cdot 10^{-5}$ mm Hg, when the gas supply to the ion source is running. Provision has been made for differential pumping, which has, however, not yet been found necessary.

Auxilliary equipment within the high-voltage electrode

As well as the upper pulleys, the wooden platform supports the equipment needed for the operation of the electron gun and the ion source. It thus carries two rectifier units of 10 kV and 20 kV for the focusing lenses, an insulation transformer for the filament current, and an electrolyser for heavy water with a Pd leak to supply the ion source with deuterium gas.

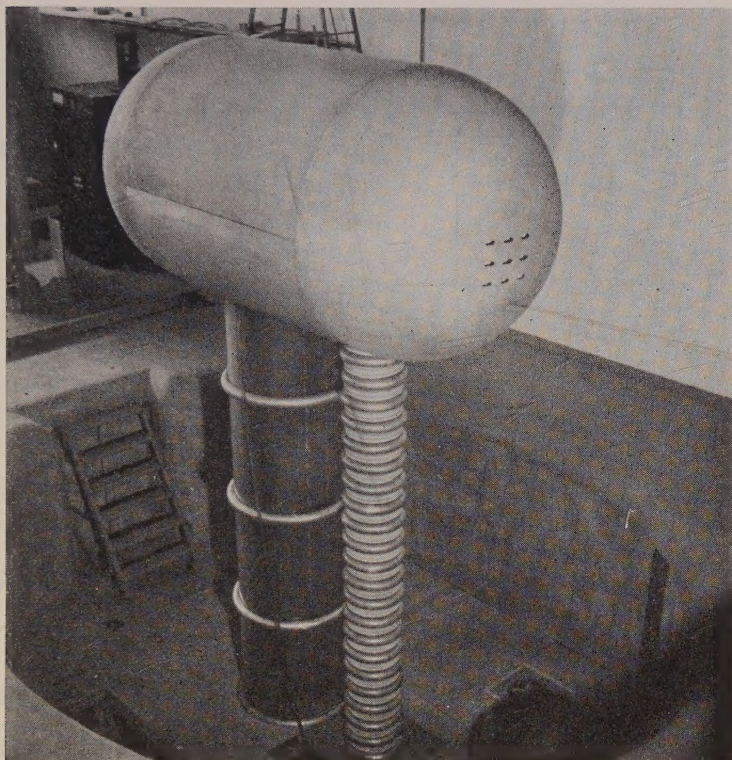


Figure 2. The electrostatic generator and the acceleration tube.

The power needed is supplied by an A.C. generator driven by one of the upper pulleys and giving 220 V, 2 kVA. Electric power can, however, also be supplied from the outside through the mantle of the high-voltage electrode, which is then grounded, and the load can be switched over to the generator, when this has been run up.

The voltages and currents can be regulated by means of variable transformers, which are controlled from the outside with silk cords. They can be read on 9 instruments placed behind holes in the mantle.

The ion source is cooled with oil, which is pumped up from the irradiation room through polyvinylchloride tubes.

Operation

The machine is controlled from the racks shown to the right in Fig. 1. There are control units for the driving motor, the charging unit, the vacuum pumps, the vacuum gauges, and the generating voltmeter. The silk cords are also controlled from this position.

The fore vacuum pressure is measured with Pirani and Brunner gauges. The high vacuum pressure is measured with an ionisation gauge.

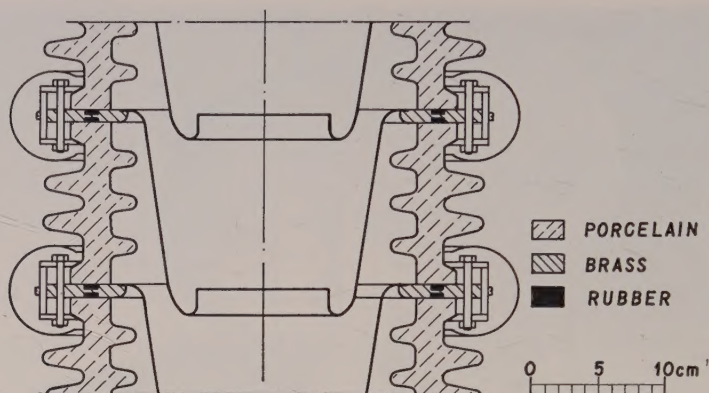


Figure 3. Cross section of the acceleration tube.

The high voltage is measured with a generating voltmeter. The voltmeter is situated in a box in the ceiling above the high voltage electrode, the rotating sector plate being in the level of the ceiling. It has been calibrated by means of a 200 kV unit, which is housed in the same hall as the electrostatic generator.

The rock and concrete that surround the irradiation room provide good protection against X-rays. In front of the control racks, however, a brick wall has been built as additional protection. The instruments in the high-voltage electrode can be read through a lead-glass window.

Several relay circuits protect the machine against accidents and mistakes in operation. Thus the diffusion pumps are switched off and rapid cooling of them is started by membrane relays, if the ordinary cooling water is stopped, and by vacuum relays, if serious vacuum trouble should occur.

Performance

The machine has been ready for use as a neutron generator for a year, and has served without any considerable trouble in an investigation by AXNER and SWENSON (1). They have only used 600–650 kV and an ion current of about $10 \mu\text{A}$. With the D-D reaction on a heavy ice target they have had a neutron radiation of 9 Curie RaBe equivalent. The intensity reached has been enough for their purpose, and relatively little work has therefore been spent on trimming the generator to a higher voltage. Running without load 900 kV has been attained, and if a suitable potential distribution could be arranged along the acceleration tube it should be possible to reach at least 1 MV.

The short-circuit current is between 600 and $700 \mu\text{A}$. If the downwardgoing parts of the belts were also made to transport charge, this current might be doubled. This could possibly give a higher maximum voltage, as the limiting factor seems to be the corona losses and perhaps leakage currents but not breakdowns.

The plexiglas column gets dusty, when the generator is running, but this does not markedly increase the leakage current. High atmospheric humidity

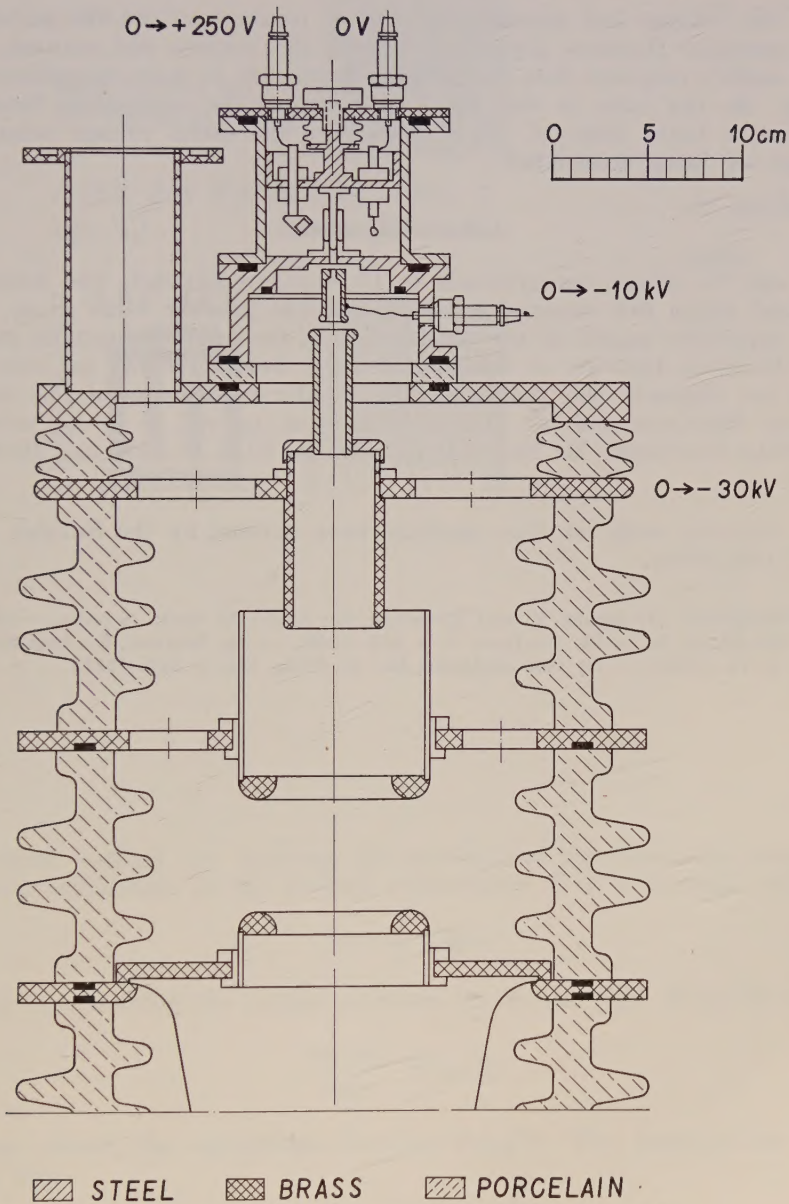


Figure 4. The top of the acceleration tube with the ion source.

affects the leakage and increases the risk of breakdown, and the performance of the generator therefore deteriorates during the summer and autumn.

The earth's magnetic field deflects the beam east or west depending on the polarity. As the tube is very long, the width of the acceleration lenses (100 mm) sets a lower limit of about 400 kV to the useful voltage range, when electrons are being accelerated.

Acknowledgements

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